

2

Measuring with Metric

Learning Outcomes

2.1 Length

- Perform measurements of length.
- Convert the metric units for length from one metric unit to another.

Prelab Question: Is nanometer, centimeter, or micrometer the larger measurement unit for length?

2.2 Weight

- Perform measurements of weight.
- Convert the metric units for weight from one metric unit to another.

Prelab Question: Would you expect the weight of a penny to be given in terms of kilograms or grams?

2.3 Volume

- Perform measurements of volume.
- Determine strategies for measuring volume in various circumstances.
- Convert the metric units for volume from one metric unit to another.

Prelab Question: What units of measurement appear on a graduated cylinder?

2.4 Temperature

- Compare and contrast the Fahrenheit (F) and Celsius (C) temperature scales.
- Perform measurements of temperature.
- Convert one unit of temperature into another using a provided equation.

Prelab Question: Water boils at 100° on which temperature scale?

Introduction

The metric system is the standard system of measurement in the sciences, including biology, chemistry, and physics (Fig. 2.1). It has tremendous advantages because all conversions, whether for volume, mass (weight), or length, are in units of ten. This base-ten system is similar to our monetary system, in which ten cents equal a dime, ten dimes equal a dollar, and so on. In this laboratory, you will gain experience making measurements of length, volume, mass, and temperature.



Figure 2.1

The metric system is the system of measurement used in scientific laboratories.

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2.1 Length

Metric units of length measurement include the **kilometer (km)**, **meter (m)**, **centimeter (cm)**, **millimeter (mm)**, **micrometer (μm)**, and **nanometer (nm)** (Table 2.1). The prefixes *milli-* (10^{-3}), *micro-* (10^{-6}), and *nano* (10^{-9}) are used with length, weight, and volume.

Table 2.1 Metric Units of Length Measurement

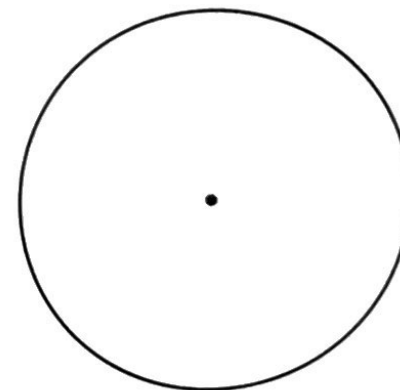
Unit	Meters	Centimeters	Millimeters	Relative Size
Kilometer (km)	1,000 (10^3) m	100,000 cm	1,000,000 mm	Largest
Meter (m)	1 m	100 cm	1,000 mm	
Centimeter (cm)	0.01 (10^{-2}) m	1 cm	10 mm	
Millimeter (mm)	0.001 (10^{-3}) m	0.1 cm	1.0 mm	
Micrometer (μm)	0.000001 (10^{-6}) m	0.0001 (10^{-4}) cm	0.001 (10^{-3}) mm	Smallest
Nanometer (nm)	0.000000001 (10^{-9}) m	0.0000001 (10^{-7}) cm	0.000001 (10^{-6}) mm	

Experimental Procedure: Length

1. Obtain a small ruler marked in centimeters and millimeters. One centimeter equals how many millimeters? _____. To express the size of small objects, such as cell contents, biologists use even smaller units of the metric system than those on the ruler. These units are the micrometer (μm) and the nanometer (nm).

According to Table 2.1, $1\ \mu\text{m} =$ _____ mm, and $1\ \text{nm} =$ _____ mm.

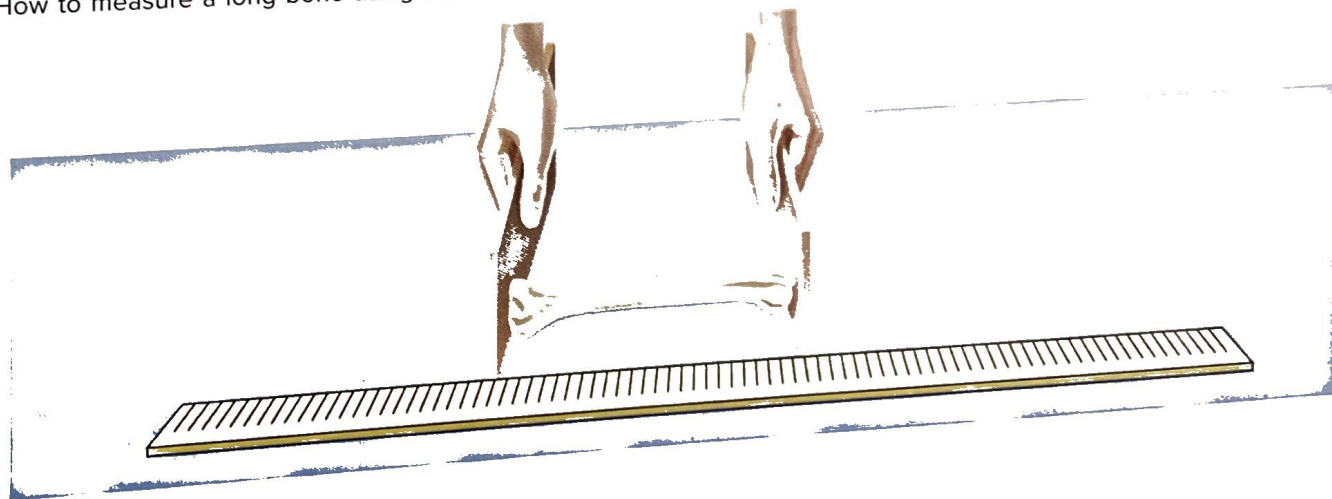
2. Measure the diameter of the circle shown to the nearest millimeter. This circle's diameter is _____ mm = _____ μm = _____ nm.



3. Obtain a meter stick. On one side, find the numbers 1 through 39, which denote inches. One meter equals 39.37 inches; therefore, 1 meter is roughly equivalent to 1 yard. Turn the meter stick over, and observe the metric subdivisions. How many centimeters are in a meter? _____. How many millimeters are in a meter? _____. How many meters are in a kilometer? _____.

4. Use the meter stick and the method shown in Figure 2.2 to measure the length of two long bones from a disarticulated human skeleton. Lay the meter stick flat on the lab table. Place a long bone next to the meter stick between two pieces of cardboard (each about 10 cm \times 30 cm), held upright at right angles to the stick. The narrow end of each piece of cardboard should touch the meter stick. The length between the cards is the length of the bone in centimeters. For example, if the bone measures from the 22 cm mark to the 50 cm mark, the length of the bone is _____ cm. If the bone measures from the 22 cm mark to midway between the 50 cm and 51 cm marks, its length is _____ mm, or _____ cm.
5. Record the length of two bones. First bone: _____ cm = _____ mm.
Second bone: _____ cm = _____ mm.

Figure 2.2 Measurement of a long bone.
How to measure a long bone using a meter stick.



2.2 Weight

Two metric units of weight are the **gram (g)** and the **milligram (mg)**. A paper clip weighs about 1 g, which equals 1,000 mg. 2 g = _____ mg; 0.2 g = _____ mg; and 2 mg = _____ g.

Experimental Procedure: Weight

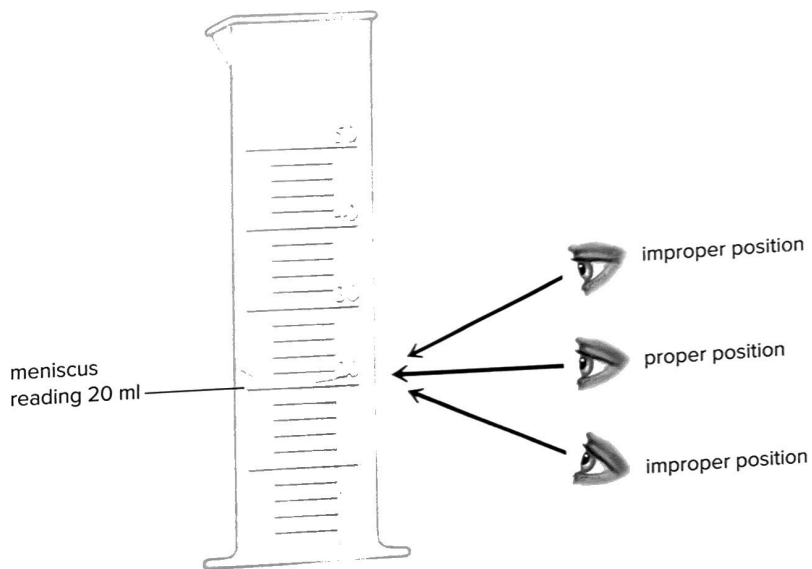
1. Use a balance scale to measure the weight of a small wooden block. _____ g = _____ mg.
2. Measure the weight of the block to the tenth of a gram. _____ g = _____ mg.
3. Measure the weight of an item small enough to fit inside the opening of a 50 ml graduated cylinder. The item, a(n) _____, is _____ g = _____ mg.

2.3 Volume

Two metric units of volume are the **liter (l)** and the **milliliter (ml)**. One liter = 1,000 ml.

Experimental Procedure: Volume

1. Graduated cylinders are used to make accurate measures of liquid volume. To compare the accuracy of a graduated cylinder to the accuracy of a beaker, fill a 100 ml beaker to the 40 ml mark. Now, pour the contents of the beaker into a 50 ml graduated cylinder. Read the volume of water at the meniscus (Fig. 2.3), or lowest margin of the liquid level. What is the actual volume of water?



2. It's useful to know about how many drops of water equal 1 ml. Fill a graduated cylinder to exactly 20 ml. A dropper bottle is necessary to obtain an exact amount. Now, add drops of water from the bottle or pipette until the meniscus reaches exactly 21 ml. About how many drops equal 1 ml of water?
3. The volume of solid objects can be measured using liquid. Your instructor will provide a small object. Hypothesize how you can measure the volume of the object with the water in the graduated cylinder.

Figure 2.3 Meniscus.
The proper way to view the meniscus.

Use your method to find the volume of the object. _____ ml

Instead of ml, the volume of solid objects is typically represented as the cube of a length measurement, such as cm^3 . Conveniently, $1 \text{ ml} = 1 \text{ cm}^3$. What is the volume of your object in cm^3 ? _____

Why is it easier to use this method to measure the volume of object compared to using length measurements to calculate the volume? _____

2.4 Temperature

There are two temperature scales: the **Fahrenheit (F)** and **Celsius (centigrade, C)** scales (Fig. 2.4). Scientists use the Celsius scale.

Experimental Procedure: Temperature

1. Study the two scales in Figure 2.4, and complete the following information:

a. Water freezes at either _____°F or _____°C.

b. Water boils at either _____°F or _____°C.

2. To convert from the Fahrenheit to the Celsius scale, use the following equation:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32^{\circ})/1.8$$

or

$$^{\circ}\text{F} = (1.8^{\circ}\text{C}) + 32$$

Human body temperature of 98°F is what temperature on the Celsius scale? _____

3. Record any two of the following temperatures in your lab environment. In each case, allow the end bulb of the Celsius thermometer to remain in or on the sample for 1 minute.

Room temperature = _____°C

Surface of your skin = _____°C

Cold tap water in a 50 ml beaker = _____°C

Hot tap water in a 50 ml beaker = _____°C

Ice water = _____°C

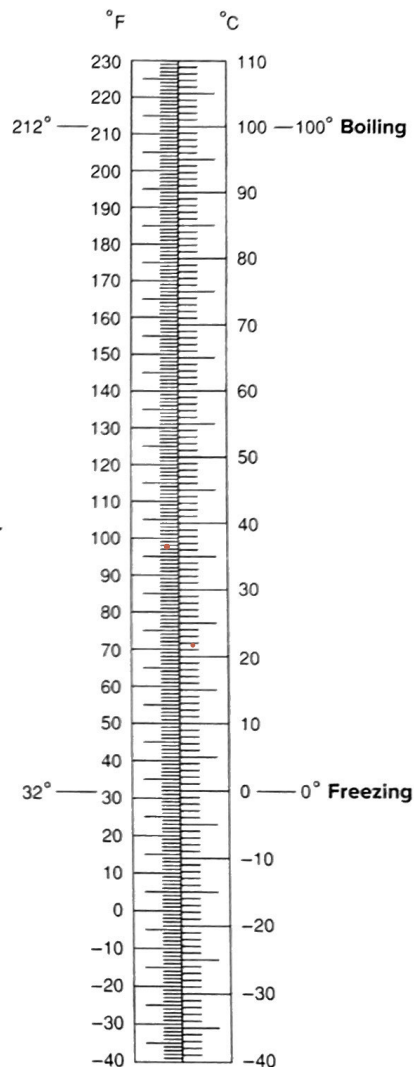


Figure 2.4 Temperature scales.

The Fahrenheit (°F) scale is on the left, and the Celsius (°C) scale is on the right.

Laboratory Review 2

1. What system of measurement is used in science?
2. Which units of measurements were examined in this lab?
3. What is the base unit for length?
4. 19 mm equals how many cm?
5. 880 mm equals how many m?
6. What instruments are used to observe objects smaller than a millimeter?
7. What is the base unit for mass?
8. What instrument is used to measure mass?
9. 2,700 mg equals how many grams?
10. One ml is equal to how many cubic centimeters?
11. 3.4 liters equals how many ml?
12. What term refers to the level you measure to in a graduated cylinder?
13. Which temperature scale is used in science?
14. 22°C equals how many degrees F?

Thought Questions

15. Describe the advantages of using the metric system you discovered during this lab.
16. Explain how you would measure the volume of a solid object, such as a rock.
17. Why is it advantageous to use a standard measurement system in all sciences?